M.E. 530.420
JHU Robot Sensors and Actuators Education Board (JHURSAEB) and MaEvArM User Manual

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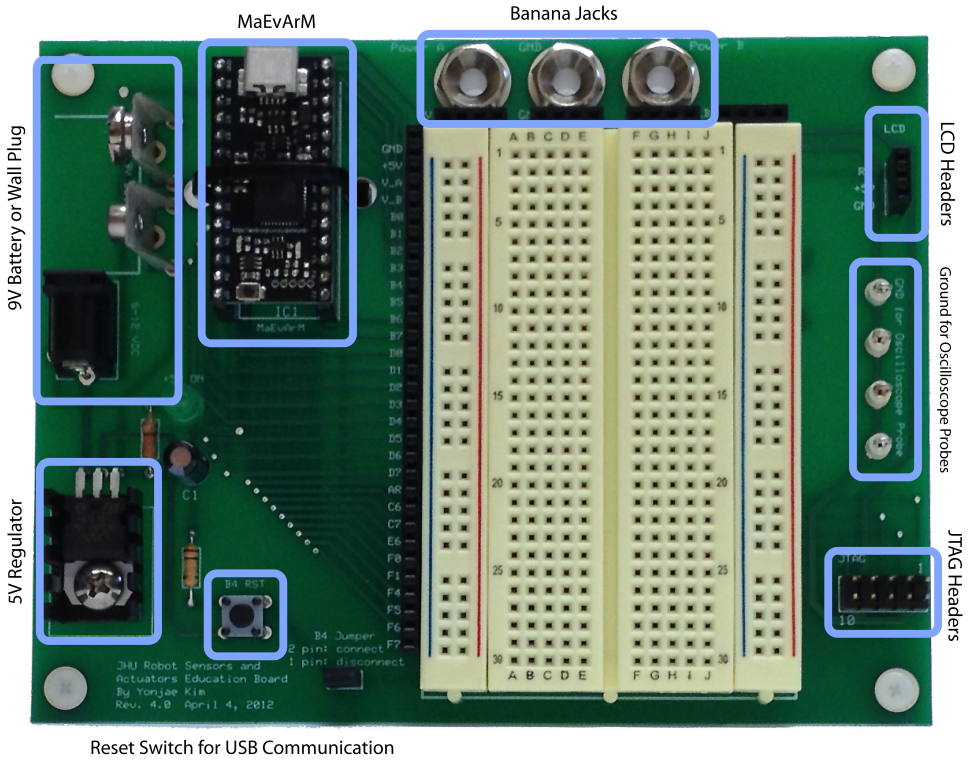
Revision 22 – July 5, 2012

Download the latest version of this manual here:
https://dscl.lcsr.jhu.edu/JHURSAEB

JHURSAEB



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0 Modification History

0.1 2011-09-14 Revision 17

First release

0.2 2011-09-20 Revision 18

0.2.1 Revised recommended user project directory to work on Windows 7 PCs in Wyman 140

This is a change to Section 3 Creating, Compiling, and Running Code on the JHURSAEB/MaEvArM:

We can't use C:\RSA_2011\your_name to store your project files because the directory is protected. Since you will be logged in as "Guest", store your projects in the following directory.

C:\Users\Guest\RSA_2011\your_name

for example:

C:\ Users\Guest\RSA_2011\Whitcomb\My_Hello_World_Project

0.2.2 Added documentation for new function USART_printf() to Section 13 USART – maevarmUSART.h/.c

Added documentation for new function USART_printf() to Section 13 USART – maevarmUSART.h/.c

0.3 2011-09-27 Revision 19 Corrected directory typos on pages iv and 4.

Example user directory corrected to read as follow in page iv and page 4:

C:\ Users\Guest\RSA_2011\Whitcomb\My_Hello_World_Project

0.4 2012-04-11 Revision 20 Update to match library updates and explanation of JHURSAEB's soft reset button

Changed font of "-Wl,-u,vfprintf" to make l (lowercase L) be differentiable from an upper case i.
Added additional explanation about usb_initialize().
Added TMR0 and TMR3 sections.

0.5 2012-06-28 Revision 22

Updated MaEvArM graphics for Rev. 4.0 of the board and fixed minor typos. Added note about setting up the USB Serial driver on Windows. Updated links to JHURSAEB website.

1 Introduction

The JHU Robot Sensors and Actuators Education Board (JHURSAEB) is a microprocessor development board for use in undergraduate robotics laboratory courses at the Department of Mechanical Engineering, Johns Hopkins University. This board utilizes at the MaEvArM microcontroller platform developed by Prof. Jonathan Fiene at the Department of Mechanical Engineering and Applied Mechanics, University of Pennsylvania. The MaEvArM utilizes Amtel's ATmega32U4 microcontroller. The USB interface built into this microcontroller allows programming of the device directly from a host computer via USB without the need for an external dongle, but the device can also be programmed and debugged through the SPI and JTAG interface.

The coding of ATmega32U4 can be written in C using AVR Studio 4 and the GCC compiler. Once compiled, the hex file can be uploaded into the microcontroller through the USB interface using the Flip program. More details on setup and starting up can be found on UPenn's MaEvArM page (link below) and in the Getting Started section.

Programming the ATmega32U4 involves manipulating individual bits in the registers to get the functions that you want. The ATmega32U4 datasheet (also below) gives extensive explanations on the usage and functions of the different modules in the microcontroller, and how to use the related registers. For the purposes of the class, we have made header files that will perform these register manipulations for you, and they are described below.

1.1 Resources

Header Files/source code (.zip): The latest version is available as a zip file here:
https://dscl.lcsr.jhu.edu/JHURSAEB

MaEvArM Page at UPenn:
https://alliance.seas.upenn.edu/~medesign/wiki/index.php/Guides/MaEvArM

MaEvArM USB Communication Page (contains download for usb source code and header):
https://alliance.seas.upenn.edu/~medesign/wiki/index.php/Guides/MaEvArM-usb

Amtel's ATmega32U4 Page (Documents section contains many sample codes):
http://www.atmel.com/dyn/products/product_card.asp?part_id=4317

Amtel's ATmega32U4 Datasheet (Provides explanation and sample codes):
http://www.atmel.com/dyn/resources/prod_documents/doc7766.pdf

1.2 JHURSAEB Board Layout

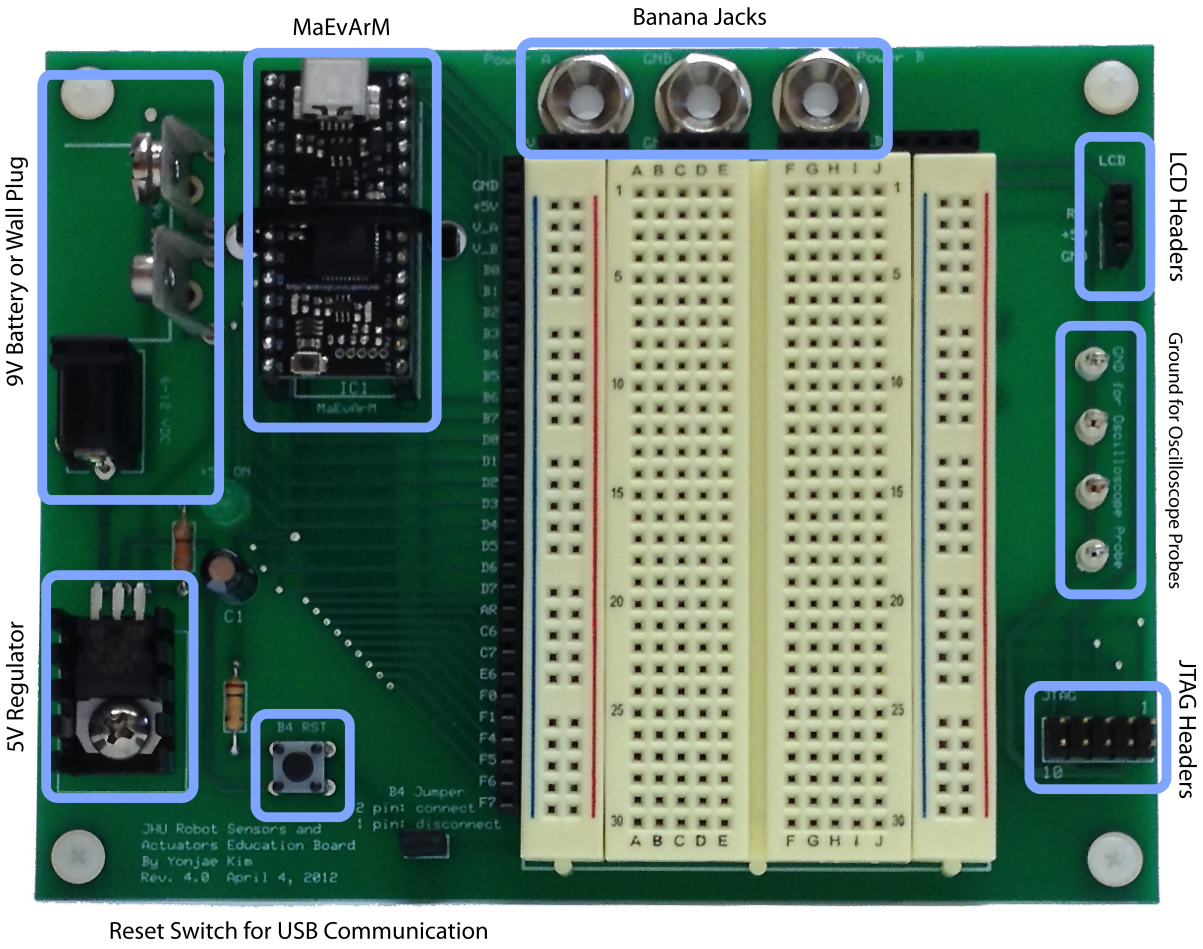


Figure 1: JHURSAEB and MaEvArM

A – MaEvArM

B – 9V Battery Slot: Converted to 5V by regulator and used to power the MaEvArM

C – AC Adapter Jack (6~12V DC): Converted to 5V by regulator and used to power the MaEvArM

D – Power LED: Will light up if power is being provided to the MaEvArM

E – B4 RST Button: A USB-use soft reset button. See below.

F – Jumpers: If you wish to disconnect the B4 RST Button, then take off the jumper and put it over only one pin.

G – Breadboard/MaEvArM Headers: Use the breadboard to construct circuits. The header pins to the left of the breadboard connect to pins on the MaEvArM, and the +5V headers at the top right connect to the V+ pin of the MaEvArM.

H – JTAG Headers: Allows connection of MaEvArM to JTAG dongle for in circuit debugging.

I – GND Test Points: Clamp oscilloscope probes' ground clamps to these to reduce some clutter.

J – LCD Backpack Pin: Connect the pins of the LCD Backpacks used in class to these headers.

K – Banana Jacks: These allow for easy connection of power from power supply using banana plugs, and connect directly to corresponding header pins. **CAUTION:** The GND banana plug connects to GND of the MaEvArM, so make sure you only connect GND to the pin.

1.3 JHURSAEB Board B4 RST Button:

If the function usb_initalize() (maevarmUSB.h/.c) is used to initialize usb connection, the B4 RST button can be used to perform a soft "reset". This sends the program back to the line of the code where usb_initialize is called, allowing users to start from the beginning of the usb interaction without disconnecting the usb terminal, as opposed to when using the MaEvArM's reset switch, which cuts off the usb connection.

The advantage of this is that there is less chance that the user will miss MaEvArM communications due to delay between initialization of connection and connection of the terminal, and that it makes it easier to start from the "beginning" of the program. **CAVEATS:** This is not a true reset, in that values of registers and variables will stay as they are when the button is pressed, so the user should write the program to take this into account. Also, the switch is connected to B4, so the user should not utilize pin B4 if usb_initalize() is called.

Sample

Case A:

```
usb_initialize();        //←B4 Button takes program back to here
char var = 0;    //variable initialized after usb_initialize
var++;           //variable starts counting up from 0 when B4 is pressed
```

Case B:

```
char var = 0;    //variable initialized before usb_initialize
usb_initialize();        //←B4 Button takes program back to here
var++;           //variable starts counting up whatever the value was when B4 was pressed
```

2 Development Environment Installation

2.1 Installing the Atmel Development Environment for Windows

Follow the instructions on the MaEvArM web page (http://medesign.seas.upenn.edu/index.php/Guides/MaEvArM-starting) for installation of the following software (all software is free):

1. AVR Studio 4: http://www.atmel.com/dyn/Products/tools_card.asp?tool_id=2725
2. WinAVR: http://winavr.sourceforge.net
3. Atmel Flip 3.4.3: http://www.atmel.com/dyn/products/tools_card.asp?tool_id=3886
4. USB Serial Communication Driver: http://www.pjrc.com/teensy/serial_install.exe

Also install this terminal emulator:

5. Terminal: https://sites.google.com/site/terminalbpp

When you plug in the MaEvArM for the first time, the "Add New Hardware" wizard cannot usually find the driver on it's own. You should point it to **C:/Program Files/Atmel/Flip 3.4.3/usb**.

2.2 Installing the JHURSAEB and MaEvArM library and header files

Download the zip file from this link:
https://dscl.lcsr.jhu.edu/JHURSAEB

The file is named RSA_library_VXX.zip, where XX is the version number. Download the latest version number. Unzip the file contents, and place all the files in the directory **C:\RSA_library**
Note: these files are already loaded on the computers in Wyman 140.

3 Creating, Compiling, and Running Code on the JHURSAEB/MaEvArM

3.1 Setting up your project:

Note: If you're on one of the Wyman 140 computers, DO NOT log in as "Station #x", as this will cause compiler errors. Log in as "Guest" instead.

1. Open: Start>All Programs>Amtel AVR Tools>AVR Studio 4
2. Select New Project or Open
   a. For New Project, choose AVR GCC, set the project name and directory, tick "Create initial file" and "Create folder", and press **Finish** (not Next)
   b. - Save your project in a new project directory under
      C:\Users\Guest\RSA_2011\your_name
      for example:
      C:\ Users\Guest\RSA_2011\Whitcomb\My_Hello_World_Project
   c. See Figure 2 for a careen shot.

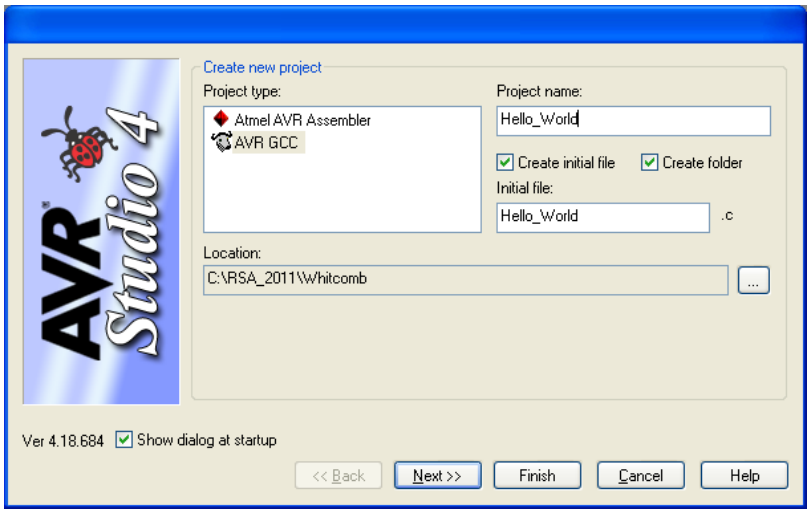


Figure 2: Creating a New Project

3. Go under Project>Configuration Options
    a. Set frequency to **16000000** (if you are not using maevarmGEN.h, then set it to 200000) and device to **atmega32U4** .
    b. See Figure 3 for a screen shot.

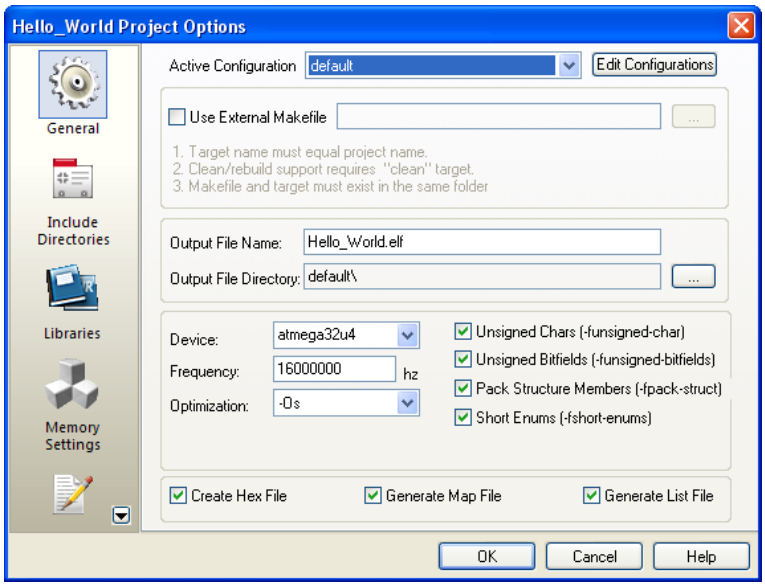


Figure 3: Setting General Project Options

    c. Click on the "Include Directories" tab on the left, and press to add folder directory that contain custom header files – in this case the RSA library directory **C:\RSA_library .**
    d. Press OK
    e. See Figure 4 for a screen shot.

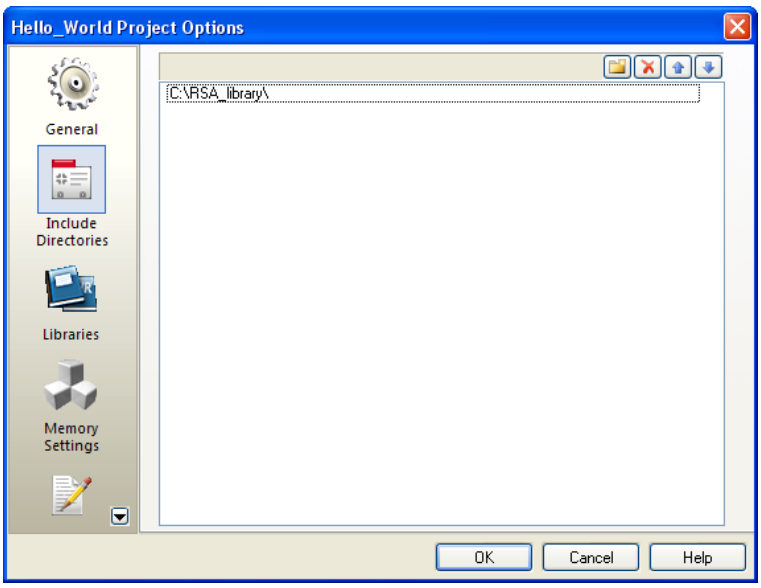


Figure 4: Setting the Include Directory Options

4. On the left hand side, right click on "**Source Files**" and **Add Existing** to include the C library files that you will use. For the simple example in Section 3, the following header files are included:

```
#include "maevarmGEN.h"    // include the general header
#include "maevarmUSB.h"    // include the USB header
#include <math.h>       // include math library
```

The first two lines reference the JHURSAEB libraries. Include the source code for these libraries in your project "source files" list. They are:

C:/RSA_library/maevarmGEN.c
C:/RSA_library/maevarmUSB.c

The third line above includes the header file **math.h** that declares math functions such as sin() and cos(). If you want to use these math functions in your program, you need to tell the linker to link the math library **libm.a** into your program executable. This is described in the next section.
See Figure 5 for a screen shot.

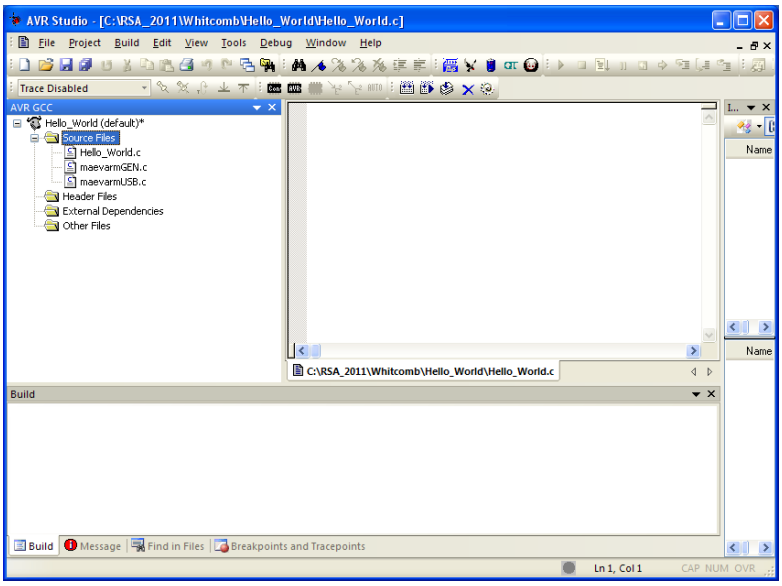


Figure 5: Specifying Library Source Files

3.2 Linker Options: Setting up your project to use usb_printf() and usb_scanf() and the standard C math library

Because a fully-functional printf and scanf functions take a lot of memory, AVR Studio offers 3 different versions of printf and scanf functions. To choose between the three, go to Project>Configuration Option, and then click on the Libraries button to get to the screen shown in Figure 6 below:

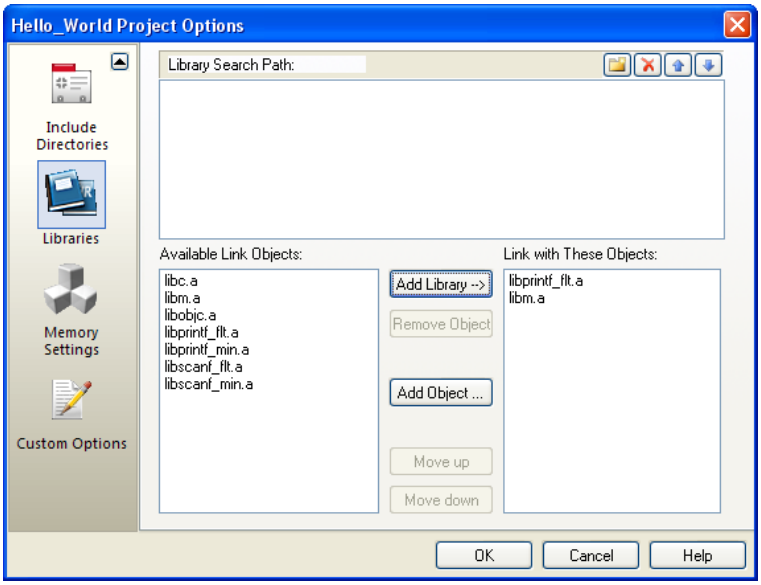


Figure 6: Setting Link Libraries

Here you can choose which of the three printf/scanf functions you want to use.

1. By default (no need to come to this menu or change anything here), the printf and scanf functions can support all of the standard formats except for floating points, and can print up to 255 characters.
2. **Recommended:** To use printf/scanf functions that can support floating point variables, and up to 65535 characters, highlight libprintf_flt.a or libscanf_flt.a and then press "Add Library->"
3. To use printf/scanf functions that are smaller than the default and have minimal functionality (w/ basic integer & string conversions and only # conversion flags support), highlight libprintf_min.a or libscanf_min.a and then press "Add Library->"

If you are not using a default option, AFTER adding the custom link object, you must also add libm.a (make sure libm.a appears under the function object under "Link with These Objects"

Lastly, after adding the desired function link objects and libm.a, click on Custom Options to reach the window shown in Figure 7 below:

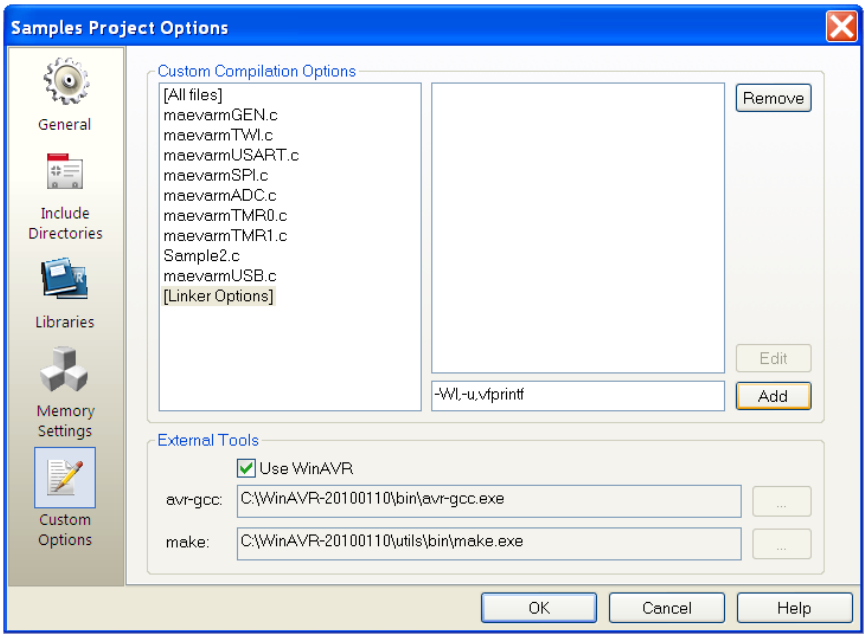


Figure 7: Specify Linker Options

On the left, under "custom Compilation Options", highlight "[Linker Options]".

- If you've added a custom linker option for printf, copy "`-Wl,-u,vfprintf`" into the box next to "Add". Make sure to copy the phrase as is, with no spaces. Then click the "Add" button.
- If you've added a custom linker option for scanf, copy "`-Wl,-u,vfscanf`" into the box next to "Add". Make sure to copy the phrase as is, with no spaces. Then click the "Add" button.

Once you've done this, click "OK" at the bottom to save your changes. The compiler will now utilize the printf/scanf functions that you've specified.

3.3 Simple Project Source Code Example

The following simple source file example can be compiled in a project. The project should include the following files:

1. This source file
2. The library source file maevarmGEN.c
3. The library source file maevarmUSB.c

If you use math functions such as sin() and cos() from the math library, you will also need to specify the math library **libm.a** in the linker options.

```
#include "maevarmGEN.h"     // include the general header
#include "maevarmUSB.h"     // include the USB header
#include <math.h>       // include math library

int main()
{ // begin of main
        int    fooi=0;    // declare int var fooi, initialize to 0

        usb_initialize(); //initialize MaEvArM USB communication

        IO_mode(B0,OUTPUT); // config B0 pin as an OUTPUT

        while(1)  // Loop forever
         { // begin of while loop
           // print to terminal
                usb_printf("Hello World fooi=%d \n", fooi);

           // increment variable fooi
           fooi = fooi + 1;

                delay_ms(500);          // wait 500 ms
                IO_out(B0,HIGH);        // set B0 pin to +5V
                delay_ms(500);                  // wait 500 ms
                IO_out(B0,LOW);         // set B0 pin to 0V

         } // end of while loop

} // end of main
```

3.4 Compiling, Downloading, and Running Your Project:

1. To build your project, press **F7**, , or "**Build**" under the Build drop-down menu
2. Open: Start>All Programs>Flip 3.4.3>Flip 3.4.3
3. Select the chip by clicking and then choosing **ATmega32U4** (Does not need to be repeated each time the program is started unless you change it)
4. Make sure the MaEvArM is connected and is in programming mode (press and hold the reset button until the green LED light up and then release, then the orange LED should remain lit to indicate that the device is in programming mode).
5. Open the connection by clicking **Ctrl+U** or >USB and then clicking "**Open**"
6. Press **Ctrl+L** or go under File and choose "Load Hex File" or choose from a list of Recent Hex Files
    a. When you compile your project, the Hex file containing the code will be generated under your project folder, in a subdirectory called **default**
    b. The name of the hex file will be something like this: C:\RSA_2011\Your_Name\Your_Project_Name\default\Your_Project_Name.hex
7. Press "**Run**" to download your program to the MaEvArm.
2. Making sure that the reset box is not ticked, click on "**Start Application**" to run your program If you don't untick the reset box, you may find that the power to your MaEvArM may oscillate. Just unplug and plug in the device to fix.
8. If you want to make use of the reset button without sending the MaEvArM into programming mode, then just press the button briefly instead of holding it.
9. After you run the program, you can use the terminal emulator to connect to the serial USB output of your program. Disconnect the terminal emulator before recompiling and downloading new code.

3.5 Serial Terminal Emulators:

In order for you to communicate with MaEvArM through the USB port on your computer, you need to download a program that will translate the digital data into characters on your screen. There are many free programs available online, and a few that are also good.

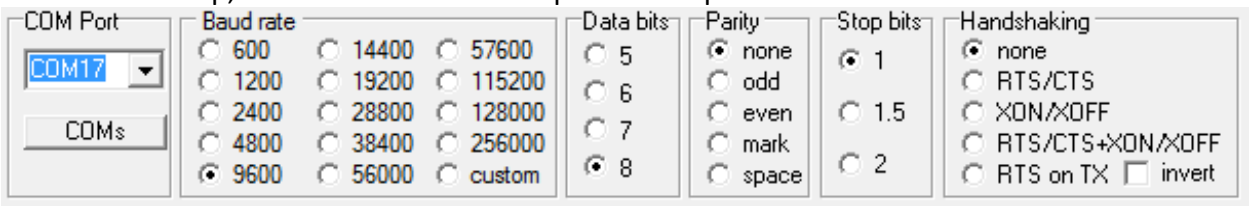
3.5.1 Terminal: (Recommended for this course)

https://sites.google.com/site/terminalbpp/

A simple executable terminal with the ability to scan for port. This is the program we will be using in the class.

Running "Terminal":

1. Open: Start>All Programs>Terminal
2. Connect the MaEvArM to the PC and wait for the device to be recognized
3. Make sure the settings at the top match the image below (with the exception of COM Port number). The MaEvArM's COM Port number will most likely be the highest numbered port. If it does not show up, then click "ReScan" to update the options.



4. Press "Connect" to connect to the device and begin communication
5. Make sure you press "Disconnect" to end communication before you disconnect the MaEvArM, put it into programming mode, or push the reset button on the MaEvArM, otherwise, the terminal will not be able to recognize the port until you press "Disconnect" and then reset the device. This is not necessary for the B4 RST Button on the JHURSAEB.

3.5.2 SerialChart:

http://code.google.com/p/serialchart/

Optimized for data plotting. Chart formatting is done purely through text commands.

3.5.3 Termite:

http://www.compuphase.com/software_termite.htm

A light software with a simple UI.

3.6 General Tips, FAQ, and Troubleshooting

"Do I have to create a new project or source code for each part of the lab?"
No. What you can do is rename your main function to something else, such as main1 or part1, and then write a new main function for the portion of the lab you are currently working on. This way, you can keep all of your main functions in one source code.

"How do I power the MaEvArM?"
When the device is connected to the computer, it gets its power through the USB port, so unless you want to have the MaEvArM run while detached from the computer, you don't need to provide external power to the MaEvArM. With the USB connected, you can access the +5V line through the pin V+. If you do want to power the MaEvArM in other ways, connect +5V to the V+ pin, and the ground to the GND pin.

"When can I use hexadecimal numbers and when can I use decimal?"
To the compiler, hexadecimal (number with prefix "0x"), decimal (just number), octal (number with prefix "0"), and in some cases, characters (characters with single quotation marks around them) are all the same and they are interchangeable. You should use whatever makes the code easier to read or is more intuitive to you.

"How do I write a number in binary?"
You can't. Use a binary/decimal/hexadecimal converter and write it in decimal or hexadecimal or create your own header file containing text macros that will make the conversions for you.

"I get a compiler error that says 'unexpected EOF while looking for matching…'"
This is most likely caused by one of the directories containing the project files having a character that will confuse the compiler. If you're working in the Wyman lab, this most likely means that you've logged in as "Station #x", and the symbol "#" is causing the error. Switch user to "guest", or put the project files into a directory that won't contain characters that will confuse the compiler.

"I uploaded my program but it doesn't do anything and stays in programming mode!"
This is most likely caused by not loading a .hex file when you first start FLIP. If you do this, the FLIP loads a blank program onto the device, which leaves only the bootloader in the MaEvArM, causing it to constantly be in programming mode.

"The timings of my functions are way off!"
Under compiler options, check to make sure that the clock has been set to the correct frequency of 16000000 (2000000 if you don't include maevarmGEN.h).

"The terminal crashes when I try to communicate with the maevarm!"
This may be caused by using the usb_initialize function and then setting the B4 pin to HIGH.

4 Using this Manual: Name of Source Code and Header File

Function _Name

Function's declaration(argument1)

Function

Description of the function's functionality.

- argument1 – description of argument
    + valid inputs for this argument (numerical value, if relevant) – descriptions if needed
- functions with many arguments may take different formats
    + Argument1, Argument2, ArgumentB, ArgumentC – equivalent to saying there are 4 possible arguments for this parameter: Argument1, Argument2, ArgumentB, ArgumentC.

Prerequisites

- Minimal list of conditions that must be fulfilled before this function can be used successfully, excluding the inclusion of corresponding header and source code
- If a function does not have this, then it most likely means that aside from including the appropriate header and source code, there are no prerequisites to using the function properly

Notes

- Special considerations that should be taken into account when using this function

Tips, Tricks, and Common Errors

- General tips to help use the function, tricks to make using the function easier, and common errors that people make

Sample

A sample code that serves as an example of how to use this function.

Note that this section will generally not include preprocessor directives (e.g. #include), but will often contain prerequisites to using this function in a specific way.

If a function does not have sample code to go along with it, it is because the function is either too simple to need one (e.g. delay_ms), or it does not make sense to provide a sample code with just this function (setup functions usually fall into this category), and its use will most likely be shown in context under a related function sample code.

Result

If relevant/necessary, terminal results from above sample code will go here.

See Also

- List of functions/appendices/sections that are closely related or may help in understanding this function

5 USB Communication – maevarmUSB.h/.c

This is a set of source code/header file that utilizes another set of code/header that is provided by UPenn for use with the MaEvArM. The UPenn files provide the initialization functions for setting up communication, and a number of transmit and receive functions that form the basis for our usb_printf and usb_scanf function.

Descriptions of the UPenn USB functions (along with the source code and header) can be found at: https://alliance.seas.upenn.edu/~medesign/wiki/index.php/Guides/MaEvArM-usb

5.1 usb_initialize()

usb_init() – Initializes usb communication. Must be called before any usb communication can take place.

usb_initialize()– Same functionality as usb_init, but allows for the usage of the B4 RST button. For details on using the B4 RST Button, see 1.3 JHURSAEB Board B4 RST Button

usb_configured() – Returns a non-zero if usb communication has been successfully initialized, returns a 0 otherwise. Can be used to check the USB communication, or to wait for communication to be established before continuing. usb_initialize() checks the connection automatically.

Sample

```
usb_init();            //initialize usb communication
while(!usb_configured());      //wait for initialization to complete

OR

usb_initialize();            //initialize usb communication w/ B4 RST

…                                                    //Rest of the code
```

5.2 usb_printf()

char usb_printf(const char * fmt, ...)

Function

The usb_printf function works like a standard printf function. The first argument should be a string, with format tags inserted as desired. There should be as many arguments following the first argument as there are format tags.

Prerequisites

- usb_init() or usb_initialize() must be called beforehand (only once)

Notes

- Certain special characters (of the \character variety) may not be displayed properly
- When communicating with the computer through the USB, you should have measures in place to account for delay between communication initialization and activation of your terminal
- By default, the usb_printf function cannot format floating points. In order to enable the full version (or the lighter version) of usb_printf, see ***Section 3.2 Linker Options: Setting up your project to use usb_printf() and usb_scanf() and the standard C math library*** on Page 7.
- See available formats here: http://www.cplusplus.com/reference/clibrary/cstdio/printf/

Tips, Tricks, and Common Errors

- Students often mistakenly use the function printf, as opposed to usb_printf. If nothing is displaying on the terminal, then this may be the reason.
- Don't forget to utilize '\n' or '\r' to create line breaks, or the terminal may become difficult to read.

Sample

```
usb_initialize();              //initialize usb communication
while(!usb_configured());      //wait for initialization to complete

usb_printf("Ways to print 77:\n");     //no formatting
usb_printf("decimal: %d\n",77);       //formatting using %d
usb_printf("4-digit hex: %04X\n", 77);  //formatting and padding using %04X
```

Result

```
Ways to print 77
decimal: 77
4-digit hex: 004D
```

See Also

- **usb_init**

5.3 usb_scanf

char usb_printf(const char * fmt, ...)

Function

Works like the standard scanf function, except that it takes its input from the USB line. The first argument should be a string containing format tags, and the following arguments should contain pointers to the variables that you wish to store values into.

Prerequisites

- usb_init or usb_initailize should be called beforehand.

Notes

- This function looks for the carriage return (CR) to indicate the end of the string from the computer, so it is critical that you check "append CR" before sending data when using this function.
- This function will pause your program until data is available on the USB line.
- See available formats here: http://cplusplus.com/reference/clibrary/cstdio/scanf/

Tips, Tricks, and Common Errors

- MAKE SURE that "append CR" has been checked before sending data
- The dereference operator (&) is needed to retrieve the pointer for most types of variables, but because arrays naturally use pointers, they don't require the reference operator

Sample

```
int number;       //initialize int
char street[256];  //initialize char array
//store first batch of characters as a decimal into number (& needed)
//store second batch of characters as a string into street (& not needed)
usb_scanf("%d %s",&number,street);
//echo input
usb_printf("You entered: %d %s",number,street);
```

Result

```
If you enter:
3400 Charles St.

The program will return:
You entered: 3400 Charles

"St." is tossed because the program was not told to store it.
```

See Also

- **usb_init**

6 General MaEvArM Functions - maevarmGEN.h/.c

This set of header/source code provide functions that are made for general usage of the MaEvArM, that is, they do not fall under any particular functional modules, consisting of functions that manipulate digital inputs/outputs of the pins and delay functions. It is highly recommended that you include this code for all of your projects, as it also contains an initialization sequence that allows the MaEvArM to operate at 16 MHz (without the initialization it will operate at 2 MHz).

6.1 delay_ms()

void delay_ms(int DELAY_TIME)

Function

The delay_ms function causes the program to pause for the desired number of milliseconds.

-DELAY_TIME – Desired number of milliseconds

+ 0~65535

Notes

- Limit is set by the size of the argument (65535 ms), but accuracy may be lost with larger numbers

- Use this instead of _delay_ms() because _delay_ms becomes inaccurate for delay times over 262.14 ms/F_CPU in MHz

6.2 delay_us()

#define delay_us(DELAY_TIME)

Function

The delay_us function causes the program to pause for the desired number of microseconds.

-DELAY_TIME – Desired number of microseconds

+ 0~65535

Notes

- This “function” is simply a text macro, and is equivalent to _delay_us

- delay_us becomes inaccurate for delay times over 768 ms/F_CPU in MHz

- using delay_us is not recommended for generating waveforms with periods less than 100 us because instructions in between will add significant time to the period

6.3 IO_mode()

char IO_mode([PIN NAME], unsigned char config)

Function

Sets one or more of the I/O pins to function as digital input or output.

SINGLE PIN MANIPULATION:

- [PIN NAME] – consists of 2 arguments {char let, char num}, but macros have been set up to accept pin name (e.g. B7, F0)

= pin# combination available

X \ #	0	1	2	3	4	5	6	7
B	■	■	■	■	■	■	■	■
C							■	■
D	■	■	■	■	■	■	■	■
E							■	
F	■	■			■	■	■	■

- config – Desired configuration
  - + INPUT (0)
  - + OUTPUT (1)

MULTIPLE PIN MANIPULATION:

- [PIN NAME] – For multiple pin manipulation, insert one of the predefined names for groups of pins
  - + ENTIREB, ENTIRED – pins B7~B0 or D7~D0
  - + UPPERB, UPPERD, UPPERF – pins B7~B4, D7~D4, or F7~F4
  - + LOWERB, LOWERD – pins B3~B0 or D3~D0
- config – Desired multiple pin configuration. Each binary digit corresponds to a pin, with the leftmost binary digit corresponding to highest pin number. For example, setting UPPERB to 0xC (binary 1100) sets pins B7 and B6 to OUTPUT (1) and pins B5 and B4 to INPUT (0)

Notes

- By default, the pins are set to input
- Every I/O pin is connected to one or more functional units in the chip, and many functions require the I/O mode to be set to either OUTPUT or INPUT to work. For example, to generate a waveform using Timer1 on the Output Compare 1 B pin (B6), pin B6 must be set to output beforehand.

Sample

```
IO_mode(B0,OUTPUT);  //sets pin B0 to output
IO_mode(LOWERD,0xA);   //0xA = binary 1010: sets pin D0 and D2 to input and
                                  //D1 and D3 to output
```

See Also

- **IO_out**
- **IO_read**

6.4 IO_out()

char IO_out([PIN NAME], unsigned char config)

Function

Outputs a logic level on one or more of the I/O pins.

SINGLE PIN MANIPULATION:

- [PIN NAME] – consists of 2 arguments {char let, char num}, but macros have been set up to accept pin name (e.g. B7, F0)

= pin# combination available

X \ #	0	1	2	3	4	5	6	7
B	■	■	■	■	■	■	■	■
C							■	■
D	■	■	■	■	■	■	■	■
E							■	
F	■	■			■	■	■	■

- config – Desired configuration
  - + LOW (0)
  - + HIGH (1)

MULTIPLE PIN MANIPULATION:

- [PIN NAME] – For multiple pin manipulation, insert one of the predefined names for groups of pins
  - + ENTIREB, ENTIRED – pins B7~B0 or D7~D0
  - + UPPERB, UPPERD, UPPERF – pins B7~B4, D7~D4, or F7~F4
  - + LOWERB, LOWERD – pins B3~B0 or D3~D0
- config – Desired multiple pin configuration. Each binary digit corresponds to a pin, with the leftmost binary digit corresponding to highest pin number. For example, setting UPPERB to 0xC (binary 1100) sets pins B7 and B6 to HIGH (1) and pins B5 and B4 to LOW (0)

Notes

- To produce digital output, the pin should be set to OUTPUT using IO_mode
- If the pin is set to INPUT, then this function will cause the pin to be pulled up if it is set HIGH, and will cause it to act as a regular input pin if it is set LOW

Sample

```
//single pin manipulation
IO_mode(B4,OUTPUT);  //set pin B4 to output
IO_out(B4,HIGH);     //output a logic 1 on B4
//multiple pin manipulation
IO_mode(UPPERD,0xF); //0xF = binary 1111: sets pin D7~D4 to output
//0xA = binary 1010: sets pin D4 and D6 to input and //5 and D7 to output
IO_out(UPPERD,0xA);
```

See Also

- **IO_mode**

6.5 IO_read()

char IO_read([PIN NAME])

Function

Returns the logic level detected on one of the I/O pins

- [PIN NAME] – consists of 2 arguments {char let, char num}, but macros have been set up to accept pin name (e.g. B7, F0)

= pin# combination available

X \ #	0	1	2	3	4	5	6	7
B								
C								
D								
E								
F								

Notes

- The pin should be set to INPUT using IO_mode and the logic level written to the pin using IO_out should be LOW before using this function.

Sample

```
IO_mode(D2,INPUT);   //set pin D2 to input
char switch = 0;   //allocate variable
switch = IO_read(D2); //store D2 reading into switch
```

See Also

- **IO_mode**

7 Analog to Digital Converter - maevarmADC.h/.c

ATmega32U4 contains a 10-bit analog to digital converter (ADC). The maximum value can be set to internal +5V, internal +2.56V, or an external voltage on the AR (analog reference) pin. The minimum is always GND. There are 12 ADC channels (11 ADC pins and 1 temperature sensor).

ADC pin # and their corresponding port pins:

0 - F0	1 - F1	4 - F4	5 - F5	6 - F6	7 - F7
8 - D4	9 - D6	10 - D7	11 - B4	12 - B5	13 - B6

14 - Temperature Sensor

7.1 ADC_enable()

char ADC_enable()

Function
Enables the ADC module.

Notes
- Must be called before AD conversion can occur.

See Also
- **ADC_disable**
- **ADC_read**
- **ADC_set_CLK**
- **ADC_set_AREF**
- **ADC_set_channel**

7.2 ADC_set_AREF()

char ADC_set_AREF(char ADC_AREF_SETTING)

Function
Sets the reference (maximum) voltage for ADC.
- ADC_AREF_SETTING – desired reference voltage source
    + AREF_Ext – AR pin voltage
    + AREF_Vcc – Internal +5V
    + AREF_256 – Internal +2.56 V

Notes
- By default, the reference voltage is set to the AR pin.

See Also
- **ADC_enable**
- **ADC_set_channel**

7.3 ADC_set_CLK()

char ADC_set_CLK(unsigned char ADC_CLK_SETTING)

Function

Sets the clock source for ADC. The clock speed determines the resolution and speed of A/D conversions.

- ADC_CLK_SETTING – Desired prescalar clock (prescaled from system clock)
  + ADC_CLK2, ADC_CLK4, ADC_CLK8, ADC_CLK16, ADC_CLK32, ADC_CLK64, ADC_CLK128 – number determines prescaling factor

Notes

- The clock speed should be between 50~200kHz for the best resolution
- By default the clock is set to system clock/2

See Also

- **ADC_enable**

7.4 ADC_set_channel()

char ADC_set_channel(unsigned char ADC_CHANNEL_SETTING)

Function

Sets ADC channel to read from.

- ADC_CHANNEL_SETTING – Desired ADC channel
  + 0-1, 4-14

  ADC channel and their corresponding port pins:

0 - F0	1 - F1	4 - F4	5 - F5	6 - F6	7 - F7
8 - D4	9 - D6	10 - D7	11 - B4	12 - B5	13 - B6

  14 - Temperature Sensor

Notes

- By default, ADC channel 0 (F0) is selected.

Tips, Tricks, and Common Errors

- If you're going to be reading consecutively from one channel, then there is no need to call this function every time; you only need to call this when you wish to change the channel.

Sample

```
ADC_set_channel(12);      //set to channel 12 (B5)
ADC_set_channel(0);       //set to channel 0 (F0)
```

See Also

- **ADC_read**
- **ADC_set_AREF**

7.5 ADC_disable_digital()

char ADC_disable_digital(unsigned char ADC_DIGI_PIN)

Function

Disables digital input on an ADC pin.

- ADC_DIGI_PIN – Desired pin-connected channel number
  + 0-1, 4-13

  ADC channel and their corresponding port pins:

0 - F0	1 - F1	4 - F4	5 - F5	6 - F6	7 - F7
8 - D4	9 - D6	10 - D7	11 - B4	12 - B5	13 - B6

Notes

- Call to disable the digital input buffer on a port pin for saving power.

See Also

- **IO_mode**
- **ADC_set_channel**

7.6 ADC_justify()

char ADC_justify(char ADC_JUST_SETTING)

Function

Justifies the results of AD conversion to the left or to the right. In layman's terms, within the 16-bits (2 registers) containing the 10 bit ADC data, the data is either aligned to the left or to the right.

- ADC_JUST_SETTING – Desired justification side
  + ADC_LEFT, ADC_RIGHT – Left or right justification

Notes

- If using ADC_read to obtain all 10 bits, then justify right.
- If using ADC_read8 to obtain only the most significant 8 bits, then justify left.
- By default, the data is justified right

See Also

- **ADC_read**
- **ADC_readH**

7.7 ADC_read()

unsigned int ADC_read()

Function

Reads and returns the 10-bit ADC value from the selected channel.

Prerequisites

- ADC must be enabled using ADC_enable

Notes

- The 10 bits of data should be right justified before using this function, or you will get a value that is multiplied by 2^6 (6 extra bits to the side)
- To read from a specific channel, you must select the channel using ADC_set_channel
- To obtain the best resolution, ADC clock speed must be set using ADC_set_CLK
- To set reference voltage to a specific value, reference must be selected using ADC_set_AREF

Sample

```
int value = 0;        //initialize variable
ADC_enable();         //enable ADC system
ADC_set_CLK(ADC_CLK8); //set ADC CLK to 1 MHz/8 = 125KHz
ADC_set_channel(4);    //set ADC channel to 4 (F4)
value = ADC_read();    //read and store value in variable
```

See Also

- **ADC_readH**
- **ADC_enable**
- **ADC_set_channel**

7.8 ADC_readH()

unsigned char ADC_readH()

Function

Reads and returns the most significant byte of the 2 data registers.

Prerequisites

- ADC must be enabled using ADC_enable

Notes

- To return an 8-bit data, the data should be left justified using ADC_justify, otherwise this function will return the 2 most significant bits
- To read from a specific channel, you must select the channel using ADC_set_channel
- To obtain the best resolution, ADC clock speed must be set using ADC_set_CLK
- To set reference voltage to a specific value, reference must be selected using ADC_set_AREF

Tips, Tricks, and Common Errors

- If 10 bits of data is unnecessary, then use this function after left justifying to obtain 8 bits of data.

Sample

```
char value = 0;       //initialize variable
ADC_enable();         //enable ADC system
ADC_set_CLK(ADC_CLK8); //set ADC CLK to 1 MHz/8 = 125KHz
ADC_set_channel(4);    //set ADC channel to 4 (F4)
ADC_justify(ADC_LEFT); //left justify data
value = ADC_readH();   //read and store value in variable
```

See Also

- **ADC_read**
- **ADC_justify**

7.9 ADC_disable()

char ADC_disable()

Function

Disables the ADC system.

Notes

- Once this function is called, no A/D conversions can occur until ADC_enable is called again.

8 Serial Peripheral Interface - maevarmSPI.h/.c

Serial Peripheral Interface is a serial communication protocol that allows a master device to communicate with a slave device using 4 lines. The 4 SPI pins on the MaEvArM are:

B0 = SS – Slave Select
B1 = SCK – Serial Clock
B2 = MOSI – Master Out Slave In
B3 = MISO – Master In Slave Out

The ATmega32U4 can be programmed to act as a master or a slave. Even when SPI is enabled, the 4 pins will act like regular I/O pins when data isn't being transferred. This means that the user must correctly initialize the port pins to be in the correct mode and have the appropriate digital output. The initialization functions will do this for you, but you must make sure that you don't change the modes or the outputs of the pins in a way that will interfere with the SPI communication.

Communication becomes active when the master brings the SS line low. The slave will communicate and receive data in sync with the SCK pulses provided by the master.

8.1 SPI_MasterInit()

char SPI_MasterInit()

Function
Initializes the SPI module as the master.

Notes
- B0 (SS), B1 (SCK), and B2 (MOSI) will be set to OUTPUT while B3 (MISO) is set to INPUT.
- All four pins are set to HIGH, meaning active high for B0~B2, and pullup for MISO

See Also
- **SPI_data_order**
- **SPI_SCK_set**
- **SS_low**
- **SS_high**

8.2 SPI_data_order()

char SPI_data_order(char SPI_DORD)

Function

Sets the data order of SPI communication.

- SPI_DORD – Desired data order
    + LSB_FIRST – Least significant bit first
    + MSB_FIRST – Most significant bit first

Notes

- By default, the data order is set to most significant bit first

See Also

- SPI_MasterInit

SPI_SCK_set

char SPI_SCK_set(char SPI_SCK_SETTING)

Function

Sets the frequency of the SPI clock.

- SPI_SCK_SETTING – Desired prescalar
    + SPI_SCK2, SPI_SCK4, SPI_SCK8, SPI_SCK16, SPI_SCK32, SPI_SCK64, SPI_SCK128
    – number determines prescaling of the CPU clock

Notes

- By default, the clock is set to CPU/4

See Also

- SPI_MasterInit

8.3 SS_low()

char SS_low()

Function
Brings SS (pin B0) line low, initiating SPI communication.

Prerequisites
- The MaEvArM should be initialized to act as the SPI master

Notes
- This is functionally equivalent to calling IO_out(B0,LOW)
- Must be called before sending or receiving data if the MaEvArM is the master, and should be called only if MaEvArM is the master.

See Also
- **SS_high**
- **SPI_MasterInit**

8.4 SS_high()

char SS_high()

Function
Pulls SS (pin B0) line high, terminating SPI communication.

Prerequisites
- The MaEvArM should be initialized to act as the SPI master

Notes
- This is functionally equivalent to calling IO_out(B0,HIGH)
- Must be called after finishing sending or receiving data if the MaEvArM is the master, and should be called only if MaEvArM is the master.

See Also
- **SS_low**
- **SPI_MasterInit**

8.5 SPI_send()

char SPI_send(unsigned char SPI_DATA)

Function

Sends a byte of data through SPI line.

- SPI_DATA – Byte to transfer
  + 0x00~0xFF

Prerequisites

- SPI should be initialized to act as a master or a slave
- As a master, the SS line should be brought low using SS_low before sending and receiving data.

Notes

- Will pause the program until it is able to send data
- As a slave, it is strongly recommended that the software check to see if the master has brought the SS line low before calling this function, as calling this beforehand will make the program wait indefinitely until it can send data.

Sample

```
SPI_MasterInit();   //Initialize SPI as master

//Leave SPI_CLK to 1/4 of CPU clock
//Leave data order at MSB first

SS_low();   //bring SS line low to start
SPI_send(0x88); //send byte 0x88
SPI_send(0xC3); //send byte 0xC3
SS_high();  //pull SS line high to end
```

See Also

- **SPI_MasterInit**

8.6 SPI_read()

unsigned char SPI_read()

Function

Receives and returns a byte of data from the SPI line.

Prerequisites

- SPI should be initialized to act as a master or a slave
- As a master, the SS line should be brought low using SS_low before sending and receiving data.

Notes

- Works by sending the byte 0x00 while receiving data, and will pause the program until it is able to send data
- As a slave, it is strongly recommended that the software check to see if the master has brought the SS line low before calling this function, as calling this beforehand will make the program wait indefinitely until it can send data.

Sample

```
char databyte = 0;  //initialize variable

SPI_MasterInit();   //Initialize SPI as master

//Leave SPI_CLK to 1/4 of CPU clock
//Leave data order at MSB first

SS_low();   //bring SS line low to start
databyte = SPI_read();  //read and store byte in variable
SS_high();  //pull SS line high to end
```

See Also

- **SPI_MasterInit**

9 8-Bit Timer/Counter 0 – maevarmTMR0.h/.c

Timers/Counters are modules that can count up or down at a steady rate. They can be used to measure the time between two events, create a waveform, or to keep track of time. The counting frequency of each timer is determined by the prescaled timer that the user assigns to that timer module, and this is used to calculate the relationship between the number of counts and the time that has elapsed.

Timer 0 is an 8-bit counter, meaning that they count from a value of 0 to 255. For 16-bit counters, use time/counter 1 or 3 (atmega32U4 also has timer4, but it does not have a library implementation at this time).

Timer 0 interacts with the following I/O pins:

B7 = Timer0 Output Compare A (OC0A)
D0 = Timer0 Output Compare B (OC0B)
D7 = Timer0 Counter Source (T0)

Terminology:

TOP – value that the counter counts to before overflowing
BOTTOM – value of 0
MAX – highest possible value, in this case, 255
OCRX – value stored in Output Compare Register X by function TMR0_X_value

9.1 TMR0_source()

char TMR0_source(unsigned char TMR0_SOURCE)

Function

Selects the clock source for Timer 0.

- TMR0_SOURCE – The source clock for Timer 0
  - + TMR0_SOURCE_NONE – No clock, stops timer
  - + TMR0_SOURCE_CLK1, TMR0_SOURCE_CLK8, TMR0_SOURCE_CLK64, TMR0_SOURCE_CLK256, TMR0_SOURCE_CLK1024 – System clock prescaled by number
  - + TMR0_SOURCE_EXTFALL – External pin (D6), counting on falling edge
  - + TMR0_SOURCE_EXTRISE – External pin (D6), counting on rising edge

Notes

- By default, the timer is not connected to a source clock (SOURCE_NONE), so this function must be called before using Timer0. Other Timer0 setup functions, however, can be called beforehand.

See Also

- **TMR0_set_mode**

9.2 TMR0_set_mode()

char TMR0_set_mode(unsigned char TMR0_MODE)

Function

Sets the counting/waveform generation mode for Timer0.

- TMR0_MODE – The desired counting/waveform generation setting
  - + TMR0_ZZZ_YYY

ZZZ - type of waveform generated

YYY - TOP, the value counter will count up to

= combination available

	NORMAL	CTC	PCPWM	FPWM
Only ZZZ				
MAX				
OCRA				

OCRA = value stored in OCR0A

Notes

- By default, Timer0 is set to NORMAL operations

Sample

```
TMR0_set_mode(TMR0_NORMAL);    //sets timer1 mode to normal
TMR0_set_mode(TMR0_PCPWM_MAX);   //sets mode to PCPWM with TOP value of 0xFF
TMR0_set_mode(TMR0_CTC_OCRA);   //sets mode to CTC with TOP value of OCRA
```

See Also

- **TMR0_source**
- **TMR0_set_mode**

9.3 TMR0_X_mode() //X = A, or B

char TMR0_X_mode(unsigned char X_MODE)

Function

Sets the behavior of the output on the Output Compare pins (OC0A – B7, OC0B – D0). The exact effect depends on the type of waveform set by TMR0_set_mode

- X_MODE – The desired pin output behavior
    + TMR0_PIN_NORMAL, TMR0_PIN_TOGGLE, TMR0_PIN_CLEAR, TMR0_PIN_SET

All waveforms:

NORMAL – Pin is disconnected and acts as regular port pin

Normal mode:

TOGGLE – Pin is toggled on compare match
CLEAR – Pin is cleared on compare match
SET – Pin is set on compare match

CTC mode:

TOGGLE– Pin is toggled on compare match
CLEAR – Pin is cleared on compare match
SET – Pin is set on compare match

FPWM mode:

TOGGLE – For A only, if TOP is OCRA, toggles pin output on compare match. OC0B acts as regular port pin.
CLEAR – Clears pin on compare match, set pin at TOP
SET – Set pin on compare match, clear pin at TOP

PCPWM:

TOGGLE – For A only, if TOP is OCRA, toggles pin output on compare match (both rising and falling). OC0B acts as regular port pin.
CLEAR – Clears pin on rising match, sets on falling match
SET – Sets pin on rising match, clears on falling match

Prerequisites

- In order to use this function to generate a PWM signal, the appropriate mode must be selected using TMR0_set_mode and the timer should set to run using TMR0_source.
- To generate an output, the corresponding pin must be set to output using IO_mode

Notes

- For PWM mode, setting the mode to CLEAR makes the comparison value proportional to duty cycle, and setting the mode to SET inverts the signal. See atmega32U4 manual section 13.6 for more details.

- The TOGGLE modes can be used to create a square wave

Sample

```
TMR0_set_mode(TMR0_PCPWM_MAX);   //sets mode to PCPWM with TOP value of 0xFF
TMR0_A_value(128);          //sets A comparison value to 128
TMR0_B_value(200);                  //sets B comparison value to 200
TMR0_A_mode(TMR0_PIN_SET);     //set inverted PWM on pin OC0A
TMR0_B_mode(TMR0_PIN_CLEAR);   //set PWM on pin OC0B
TMR0_source(TMR0_SOURCE_CLK1); //connect Timer0 to a clock and begin PWM
```

See Also

- **TMR0_set_mode**
- **TMR0_source**

9.4 TMR0_X_value() //X = A or B

char TMR0_X_value(unsigned char COUNTER_VALUE)

Function

Stores the comparison value for Timer0's output compare units

- COUNTER_VALUE – desired comparison value
  + 0x00~0xFF

Sample

```
TMR1_A_value(0x0F);  //set A comparison value to 15
TMR1_B_value(0xFF);  //set B comparison value to 255
```

See Also

- **TMR0_X_mode**

10 16-Bit Timer/Counter 1 – maevarmTMR1.h/.c

Timers/Counters are modules that can count up or down at a steady rate. They can be used to measure the time between two events, create a waveform, or to keep track of time. The counting frequency of each timer is determined by the prescaled timer that the user assigns to that timer module, and this is used to calculate the relationship between the number of counts and the time that has elapsed.

Timer1 is a 16-bit timer, while the atmega32U4 has an 8-bit CPU. This means that the CPU must take a special procedure to interact with registers that contain 16-bits, during which interrupts will lead to errors. Therefore, all functions that interact with the 16-bit registers will disable interrupts before the read/write operation, and will enable them once the operation is done.

The functionality of Timer1 is nearly identical to that of Timer3

Timer 1 interacts with the following I/O pins:

B5 = Timer1 Output Compare A (OC1A)
B6 = Timer1 Output Compare B (OC1B)
B7 = Timer1 Output Compare C (OC1C)
D4 = Timer1 Input Compare Pin (ICP1)
D6 = Timer1 Counter Source (T1)

Terminology:

TOP – value that the counter counts to before overflowing
BOTTOM – value of 0
MAX – highest possible value, in this case, 65535
ICR – value stored in Input Compare Register from input compare.
OCRX – value stored in Output Compare Register X by function TMR1_X_value

10.1 TMR1_source()

char TMR1_source(char source)

Function

Selects the clock source for Timer 1.

- source – The source clock for Timer 1
    + TMR1_SOURCE_NONE – No clock, stops timer
    + TMR1_SOURCE_CLK1, TMR1_SOURCE_CLK8, TMR1_SOURCE_CLK64, TMR1_SOURCE_CLK256, TMR1_SOURCE_CLK1024 – System clock prescaled by number
    + TMR1_SOURCE_EXTFALL – External pin (D6), counting on falling edge
    + TMR1_SOURCE_EXTRISE – External pin (D6), counting on rising edge

Notes

- By default, the timer is not connected to a source clock (SOURCE_NONE), so this function must be called before using Timer1. Other Timer1 setup functions, however, can be called beforehand.

See Also

- **TMR1_set_mode**
- **TMR1_IC_read**

10.2 TMR1_set_mode()

char TMR1_set_mode(char setting)

Function

Sets the counting/waveform generation mode for Timer1.

- setting – The desired counting/waveform generation setting
  + TMR1_ZZZ_YYY

  ZZZ - type of waveform generated

  YYY - TOP, the value counter will count up to

  = combination available

	NORMAL	CTC	PCPWM	FPWM	PCFPWM
Only ZZZ					
8 (0xFF)					
9 (0x1FF)					
10 (0x3FF)					
ICR					
OCRA					

OCRA = value stored in OCR1A ICR = value stored in ICR1

Notes

- By default, Timer1 is set to NORMAL operation
- Choosing a mode with ICR as the TOP will disable Input Capturing

Sample

```
TMR1_set_mode(TMR1_NORMAL);    //sets timer1 mode to normal
TMR1_set_mode(TMR1_PCPWM_8);   //sets mode to PCPWM with TOP value of 0xFF
TMR1_set_mode(TMR1_CTC_ICR);   //sets mode to CTC with TOP value of ICR
```

See Also

- **TMR1_source**
- **TMR1_X_mode**

10.3 TMR1_X_mode() //X = A, B, or C

char TMR1_X_mode(unsigned char setting)

Function

Sets the behavior of the output on the Output Compare pins (OC1A - B5, OC1B - B6, OC1C - B7). The exact effect depends on the type of waveform set by TMR1_set_mode

- setting – The desired pin output behavior
  + TMR1_PIN_NORMAL, TMR1_PIN_TOGGLE, TMR1_PIN_CLEAR, TMR1_PIN_SET

All waveforms:

NORMAL - pin is disconnected and acts as regular port pin

CTC/Normal (from X_mode) mode:

TOGGLE - pin is toggled on compare match

CLEAR - pin is cleared on compare match

SET - pin is set on compare match

FPWM mode:

TOGGLE - For A only, if TOP is ICR or OCRA, toggles pin output on compare match. Otherwise normal pin operation.

CLEAR - Clears pin on compare match, set pin at TOP

SET - Set pin on compare match, clear pin at TOP

PCPWM/PFCPWM:

TOGGLE - For A only, if TOP is ICR or OCRA, toggles pin output on compare match (both rising and falling). Otherwise normal pin operation.

CLEAR - Clears pin on rising match, sets on falling match

SET - Sets pin on rising match, clears on falling match

Prerequisites

- In order to use this function to generate a PWM signal, the appropriate mode must be selected using TMR1_set_mode and the timer should set to run using TMR1_source.
- To generate an output, the corresponding pin must be set to output using IO_mode.

Notes

- For PWM mode, setting the mode to CLEAR makes the comparison value proportional to duty cycle, and setting the mode to SET inverts the signal. See atmega32U4 manual section 14.8 for more details.
- The TOGGLE modes can be used to create a square wave

Sample

```
TMR1_set_mode(TMR1_PCPWM_8);   //sets mode to PCPWM with TOP value of 0xFF
TMR1_A_value(128);          //sets A comparison value to 128
TMR1_B_value(200);                  //sets B comparison value to 200
TMR1_A_mode(TMR1_PIN_SET);     //set inverted PWM on pin OC1A
TMR1_B_mode(TMR1_PIN_CLEAR);   //set PWM on pin OC1B
TMR1_source(TMR1_SOURCE_CLK1); //connect Timer1 to a clock and begin PWM
```

See Also

- **TMR1_set_mode**
- **TMR1_source**

10.4 TMR1_X_value() //X = A, B, or C

char TMR1_A_value(unsigned int COUNTER_VALUE)

Function

Stores the comparison value for Timer1's output compare units

- COUNTER_VALUE – desired comparison value
  + 0x0000~0xFFFF

Notes

- This function involves writing to a 16 bit register, so interrupts are disabled during a part of the function.

Sample

```
TMR1_A_value(0x0FFF);   //set A comparison value to 4095
TMR1_B_value(65500);    //set B comparison value to 65500
TMR1_C_value(20);       //set C comparison value to 20
```

See Also

- **TMR1_X_mode**

10.5 TMR1_IC_noise_canceller()

char TMR1_IC_noise_canceller(char setting)

Function

Activates or deactivates the built-in Input Capture noise canceller.

- setting – desired Noise Cancel setting
    + TMR1_NC_ON – noise canceller on
    + TMR1_NC_OFF – noise canceller off

Notes

- The noise canceller works by sampling the pin repeatedly and making sure that the pin remains changed for 4 counts in a row before storing the count value. This causes the stored counter value to be 4 counts greater than the count corresponding to the event.

Tips, Tricks, and Common Errors

- If you're using the counter to store the duration (difference between two events), the 4 counts of difference won't matter as long as the noise canceller is either on or off for when both events occur.

See Also

- **TMR1_IC_read**

10.6 TMR1_IC_edge_select()

char TMR1_IC_edge_select(char setting)

Function

Determines whether the Input Capture Unit is triggered by a rising edge or a falling edge. In other words, sets the definition of an "event".

- setting – desired edge selection
    + TMR1_ES_RISING – Rising edge select
    + TMR1_ES_FALLING – Falling edge select

Notes

- By default, the IC unit is set to be triggered by a falling edge

See Also

- **TMR1_IC_read**

10.7 TMR1_IC_read()

unsigned int TMR1_IC_read()

Function

Waits for a flag to be set by an event on the Input Capture pin (ICP1 – D4) and returns the counter value at the event. After reading the value, the function clears the flag.

Prerequisites

- ICP1 (pin D4) should be set to input before calling this function.
- Timer1 clock must be set to run using the TMR1_source functions.
- The TOP of the Output Compare unit set by TMR1_set_mode must not equal ICP

Notes

- This function waits until the flag is set and returns the store value, but it does not discriminate as to when this event occurred. If an event had occurred before calling this function and the flag is set, it will immediately return the stored counter value.

Tips, Tricks, and Common Errors

- To guarantee returning of a count value of a future event, call the function TMR1_IC_clear right before calling this function.

Sample

```
int value = 0;                  //initialize variable

TMR1_edge_select(TMR1_ES_RISING);  //select rising edge
TMR1_IC_clear();                //clear IC flag
value = TMR1_IC_read();         //read and store the value
```

See Also

- **TMR1_source**
- **TMR1_IC_clear**
- **TMR1_IC_edge_select**
- **TMR1_IC_noise_canceller**

10.8 TMR1_pulsein()

unsigned int TMR1_pulsein()

Function

Waits for a square pulse to occur on the Input Compare Pin 1 (ICP1), and returns the length of the pulse in term of timer counts.

Prerequisites

- ICP1 (pin D4) should be set to input before calling this function.
- Timer1 clock must be set to run using the TMR1_source functions.
- The TOP of the Output Compare unit set by TMR1_set_mode must not equal ICP.

Notes

- This function clears the event flag before reading the rising edge, and therefore it is not necessary to clear the flag before calling this function.
- The current version of this function only accounts for the possibility of a single overflow, so if the duration of the pulse is large enough to cause the counter to overflow twice, then the returned value will be inaccurate.

Tips, Tricks, and Common Errors

- If Timer1 source is set to be 1 MHz (no prescaling if system clock is 1MHz, divide by 8 if system clock is 8 MHz, etc.), then the function returns the duration of the pulse in microseconds.

Sample

```
TMR1_source(TMR1_SOURCE_CLK1);  //set clock source to system clock
mode_D(4, input);           //set pin D4 to input

int duration = 0;           //initialize variable
duration = TMR1_pulsein();     //measure pulse duration and store
```

See Also

- **TMR1_IC_read**
- **TMR1_source**

10.9 TMR1_IC_clear()

char TMR1_IC_clear()

Function

Clears the Input Capture unit event flag.

Notes

- This function clears the flag that indicates that an event has occurred, but does not erase the count value that was stored when the event occurred.

See Also

- **TMR1_IC_read**

11 16-Bit Timer/Counter 3 – maevarmTMR3.h/.c

Timer3 is a 16-bit timer that is nearly identical in function to that of Timer 1. Functions and arguments are provided below, but for details on their use, refer to their Timer 1 counterparts in the previous section.

Note that although Timer 3 has functions and registers to utilize output compare B and C, the pins to interact with them do not exist. The functions have been provided, however, because they can likely be used to generate interrupts.

Timer 3 interacts with the following I/O pins:

C6 = Timer3 Output Compare A (OC3A)
C7 = Timer3 Input Compare Pin (ICP3)
D6 = Timer1 Counter Source (T1)

Terminology:

TOP – value that the counter counts to before overflowing
BOTTOM – value of 0
MAX – highest possible value, in this case, 65535
ICR – value stored in Input Compare Register from input compare.
OCRX – value stored in Output Compare Register X by function TMR3_X_value

11.1 TMR3_source()

char TMR3_source(char source)

Function

Selects the clock source for Timer 3.

- source – The source clock for Timer 3
  - + TMR3_SOURCE_NONE – No clock, stops timer
  - + TMR3_SOURCE_CLK1, TMR3_SOURCE_CLK8, TMR3_SOURCE_CLK64, TMR3_SOURCE_CLK256, TMR3_SOURCE_CLK1024 – System clock prescaled by number
  - + TMR3_SOURCE_EXTFALL – External pin (D6), counting on falling edge
  - + TMR3_SOURCE_EXTRISE – External pin (D6), counting on rising edge

See Also

- TMR1_source

11.2 TMR3_set_mode()

char TMR3_set_mode(char setting)

Function

Sets the counting/waveform generation mode for Timer3.

- setting – The desired counting/waveform generation setting
  - + TMR1_ZZZ_YYY

ZZZ - type of waveform generated

YYY - TOP, the value counter will count up to

= combination available

	NORMAL	CTC	PCPWM	FPWM	PCFPWM
Only ZZZ					
8 (0xFF)					
9 (0x1FF)					
10 (0x3FF)					
ICR					
OCRA					

OCRA = value stored in OCR3A ICR = value stored in ICR3

See Also

- TMR1_set_mode

11.3 TMR3_X_mode() //X = A, B, or C

char TMR3_X_mode(unsigned char setting)

Function

Sets the behavior of the output on the Output Compare pin (OC3A –C6). The exact effect depends on the type of waveform set by TMR1_set_mode

- setting – The desired pin output behavior
    + TMR3_PIN_NORMAL, TMR3_PIN_TOGGLE, TMR3_PIN_CLEAR, TMR3_PIN_SET

Prerequisites

- In order to use this function to generate a PWM signal, the appropriate mode must be selected using TMR3_set_mode and the timer should set to run using TMR3_source.
- To generate an output, the corresponding pin must be set to output using IO_mode.

Notes

- Pins OC3B and OC3C do NOT exist.

See Also

- **TMR1_X_mode**

11.4 TMR3_X_value() //X = A, B, or C

char TMR3_A_value(unsigned int COUNTER_VALUE)

Function

Stores the comparison value for Timer3's output compare units

- COUNTER_VALUE – desired comparison value
    + 0x0000~0xFFFF

Notes

- Pins OC3B and OC3C do NOT exist.

See Also

- **TMR1_X_value**

11.5 TMR3_IC_noise_canceller()

char TMR3_IC_noise_canceller(char setting)

Function

Activates or deactivates the built-in Input Capture noise canceller.

- setting – desired Noise Cancel setting
    + TMR3_NC_ON – noise canceller on
    + TMR3_NC_OFF – noise canceller off

See Also

- **TMR1_IC_noise_canceller**

11.6 TMR3_IC_edge_select()

char TMR3_IC_edge_select(char setting)

Function

Determines whether the Input Capture Unit is triggered by a rising edge or a falling edge. In other words, sets the definition of an “event”.

- setting – desired edge selection
    + TMR1_ES_RISING – Rising edge select
    + TMR1_ES_FALLING – Falling edge select

See Also

- **TMR1_IC_edge_select**

11.7 TMR3_IC_read()

unsigned int TMR3_IC_read()

Function

Waits for a flag to be set by an event on the Input Capture pin (ICP3 – C7) and returns the counter value at the event. After reading the value, the function clears the flag.

Prerequisites

- ICP3 (pin C7) should be set to input before calling this function.
- Timer3 clock must be set to run using the TMR3_source functions.
- The TOP of the Output Compare unit set by TMR3_set_mode must not equal ICP

See Also

- **TMR1_IC_read**

11.8 TMR3_pulsein()

unsigned int TMR3_pulsein()

Function

Waits for a square pulse to occur on the Input Compare Pin 3 (ICP3), and returns the length of the pulse in term of timer counts.

Prerequisites

- ICP3 (pin C7) should be set to input before calling this function.
- Timer3 clock must be set to run using the TMR3_source functions.
- The TOP of the Output Compare unit set by TMR3_set_mode must not equal ICP.

See Also

- **TMR1_pulsein**

11.9 TMR3_IC_clear()

char TMR3_IC_clear()

Function

Clears the Input Capture unit event flag.

See Also

- **TMR1_IC_clear**

12 Two Wire Interface (I2C) Functions - maevarmTWI.h/.c

The TWI module uses the I2C protocol to allow serial communication with peripheral devices attached to the MaEvArM. Amtel calls their I2C module TWI due to patent issues. On the MaEvArM, pin D0 corresponds to SCL and pin D1 corresponds to SDA.

12.1 TWI_enable()

char TWI_enable()

Function

Enables the TWI module and have it take over pins D0 (SCL) and D1 (SDA).

Notes

- This function is NOT necessary in order to use the TWI module, as calling TWI_start also activates the TWI module. This function should be used if you want to have the TWI module take control of the TWI pins before starting transmission or reception of data. When TWI takes control of the pins, they are pulled high.

See Also

- **TWI_bitrate**
- **TWI_start**
- **TWI_disable**

12.2 TWI_bitrate()

void TWI_bitrate(unsigned char TWI_BIT_RATE)

Function

Sets the value of the bitrate register, which is one of the two values that determine the frequency of SCL. The other value, prescale, usually does not need to be changed (by default 0).

Notes

- SCL frequency = CPU freq/(16+2*(BR)*4^(PS))
- Bitrate value should be greater than 10 when operating as the master

See Also

- **TWI_enable**
- **TWI_start**

12.3 TWI_start()

char TWI_start()

Function

Generates the TWI start condition (low SDA while SCL is high).

Notes

- Must be called before transmission of address and data.

See Also

- **TWI_enable**
- **TWI_bitrate**
- **TWI_tx_address**
- **TWI_stop**

12.4 TWI_tx_address()

char TWI_tx_address(unsigned char TWI_ADDRESS_BYTE)

Function

Transfers the address byte entered as the argument.

- TWI_ADDRESS_BYTE – address byte to transmit
  + 0x00~0xFF

Prerequisites

- Must have started the transmission sequence using TWI_start

Notes

- Needs to be called in order to select the peripheral device to communicate with.
-This function is NOT equivalent to TWI_tx_data, and should not be used to send data.

See Also

- **TWI_start**
- **TWI_tx_data**

12.5 TWI_tx_data()

char TWI_tx_data(unsigned char TWI_DATA_BYTE)

Function

Transfers the data byte entered as the argument.

Prerequisites

- Must have started the transmission sequence using TWI_start

Notes

- This function is NOT equivalent to TWI_tx_address, and should not be used to send address.
- Once the start condition has been generated and the address byte is transferred successfully, this function can be called multiple times before stopping (as long as the data will be valid with the peripheral device)

Sample

```
TWI_start();   //generate start condition
TWI_tx_address(0x58);  //send address byte 0x58
TWI_tx_data(0x80);     //send data byte 0x80
TWI_stop();    //generate stop condition
```

See Also

- **TWI_start**
- **TWI_tx_address**
- **TWI_stop**

12.6 TWI_stop()

char TWI_stop()

Function

Generates the stop condition (SDA pulled high while SCL is high), ending the transmission.

Prerequisites

- Must have started the transmission sequence using TWI_start and have sent at least one byte of data

Notes

- MUST be called at the end of every transmission to terminate. You cannot start another transmission until this function is called.
- This does not release the TWI pins. TWI module remains enabled after calling this function.

See Also

- **TWI_start**

12.7 TWI_disable()

char TWI_disable()

Function

Disables the TWI module and releases the pins.

Notes

- This will make pins D0 and D1 behave like normal I/O pins again. In order to communicate using TWI again, the TWI module must be enabled using TWI_enable.

See Also

- **TWI_enable**

13 USART – maevarmUSART.h/.c

USART (Universal Synchronous and Asynchronous serial Receiver and Transmitter) is a serial communication unit with independent lines for transmitting and receiving data. The data can be transmitted synchronously (in sync with a clock signal) or asynchronously (no syncing). Unlike other communication protocols, USART does not require both transmission and reception lines to be connected in order to communicate, instead relies on cues embedded in the protocol to let the devices know the beginning and the end of transmission. The USART module in the MaEvArM utilizes TTL protocol, meaning that 5V is logic 1, and 0V is logic 0.

The USART system uses pins D2, D3 and D5 on the MaEvArM

D2 - RXD1 (Receive Data)
D3 - TXD1 (Transmit Data)
D5 - XCK1 (Clock)

13.1 USART_init()

char USART_init(unsigned int baud, char setting)

Function

Initializes USART as synchronous or asynchronous with a specific baud rate.

- baud – desired baud rate
  + 0x0000~0xFFFF
- setting – asynchronous or synchronous communication
  + USART_SYNC
  + USART_ASYNC

Notes

- Most commonly used baud rate is 9600. There will be a lower limit on baud rate due to the speed of the CPU speed
- This function DOES NOT enable transmission or reception or takes control over the I/O pins. Because the two functions are independent of each other and users may find themselves using one or the other, enabling and disabling of transmission and reception have been separated into their own functions.

See Also

- **USART_tx_enable**
- **USART_rx_enable**

13.2 USART_size()

char USART_size(char size)

Function

Sets the bit size of the data to be transmitted or received.

- size – number of bits
    + 5~9

Notes

- Because atmega32U4 has an 8-bit CPU, working with 9 bit data requires extra steps. Therefore, make sure to use the appropriate 9-bit functions that have been written.
- By default, the data size is set to 8.

See Also

- **USART_tx9**
- **USART_rx9**

13.3 USART_set_parity()

char USART_set_parity(char setting)

Function

Sets the parity bit option.

- setting – desired parity option
    + USART_PARITY_OFF
    + USART_PARITY_EVEN
    + USART_PARITY_ODD

Notes

- By default, parity bits are turned off

13.4 USART_set_stopbit()

char USART_set_stopbit(char setting)

Function

Sets the size of the stop bit.

- setting – desired stop bit size
    + USART_STOPBIT1
    + USART_STOPBIT2

Notes

- By default, the stop bit size is set to 1

13.5 USART_tx_enable()

char USART_tx_enable()

Function

Enables the USART transmission unit.

Notes

- This function must be called before sending data from atmega32U4
- This function gives the USART module control over the TXD1 pin (D3)

See Also

- **USART_tx**
- **USART_tx9**
- **USART_tx_disable**

13.6 USART_tx()

char USART_tx(unsigned char data)

Function

Transmits data on TXD1 (D3) pin, and accepts data size of 5~8 bits.

- data – data to be transmitted
  + 0x00~0xFF

Prerequisites

- Baud rate must be set using USART_init
- If sending data with size other than 8-bits, the data size must be set using USART_size
- Transmission must be enabled using USART_tx_enable

Notes

- This function can send 5~8 bits of data (see USART_tx9 for sending 9 bits of data), but it does not check to see what the size setting is. So if the size is set to 5, and you input an 8-bit data into this function, then the top 3 bits will be masked and only the lower 5 bits will be sent.

Sample

```
USART_init(9600, USART_ASYNC);  //set baud rate to 9600, asynchronous
USART_tx_enable();          //enable transmission
USART_tx('g');              //transmit the character 'g'
USART_tx(103);              //equivalent to above. ASCII for 'g' is 103
```

See Also

- **USART_tx_enable**
- **USART_tx9**

13.7 USART_tx9()

char USART_tx9(unsigned int data)

Function

Transmits 9 bits of data on TXD1 (D3) pin.

- data – data to be transmitted
  + 0x000~0x1FF

Prerequisites

- Baud rate must be set using USART_init
- Data size must be set to 9 bits using USART_size
- Transmission must be enabled using USART_tx_enable

Notes

- This function should only be used to send 9-bits of data. For other data sizes, see function USART_tx

Sample

```
USART_init(9600, USART_ASYNC);  //set baud rate to 9600, asynchronous
USART_size(9);              //set data size to 9 bits
USART_tx_enable();          //enable transmission
USART_tx9(400);             //send decimal number 400
```

See Also

- **USART_tx_enable**
- **USART_size**
- **USART_tx**

13.8 USART_tx_disable()

char USART_tx_disable()

Function

Disables the USART transmission unit.

Notes

- Once this function has been called, pin D3 will be released and data cannot be transmitted until USART_tx_enable is called again.

See Also

- **USART_tx_enable**

13.9 USART_rx_enable()

char USART_tx_enable()

Function

Enables the USART reception unit.

Notes

- This function must be called before receiving data
- This function gives the USART module control over the RXD1 pin (D2)

See Also

- **USART_rx**
- **USART_rx9**
- **USART_rx_disable**

13.10 USART_rx()

unsigned char USART_rx()

Function

Receives data from the RXD1 (D2) pin, and returns data size of 5~8 bits.

Prerequisites

- Baud rate must be set using USART_init
- If receiving data with size other than 8-bits, the data size must be set using USART_size
- Reception must be enabled using USART_rx_enable

Notes

- This function can return 5~8 bits of data (see USART_rx9 for receiving 9 bits of data), but it does not check to see what the size setting is. So if the size is set to 5, and you send in a signal with 8 bits, then this is likely to cause errors in handling the data.

Sample

```
USART_init(9600, USART_ASYNC);  //set baud rate to 9600, asynchronous
char data = 0;              //initialize variable
USART_tx_enable();          //enable transmission
data = USART_rx();          //receive and store data
```

See Also

- **USART_rx_enable**
- **USART_rx9**

13.11 USART_rx9()

unsigned int USART_rx9()

Function

Receives and returns 9 bits of data from the TXD1 (D3) pin.

- data – data to be transmitted
  + 0x000~0x1FF

Prerequisites

- Baud rate must be set using USART_init
- Data size must be set to 9 bits using USART_size
- Reception must be enabled using USART_rx_enable

Notes

- This function should only be used to return 9-bits of data. For other data sizes, see function USART_rx. If you send in a signal with more than 9 bits, then this is likely to cause errors in handling the data.

Sample

```
USART_init(9600, USART_ASYNC);  //set baud rate to 9600, asynchronous
int data = 0;               //initialize variable
USART_tx_enable();          //enable transmission
data = USART_rx9();         //receive and store data
```

See Also

- **USART_rx_enable**
- **USART_size**
- **USART_rx**

13.12 USART_rx_disable()

char USART_rx_disable()

Function

Disables the USART reception unit.

Notes

- Once this function has been called, pin D2 will be released and data cannot be received until USART_rx_enable is called again.

See Also

- **USART_rx_enable**

13.13 USART_printf()

int USART_printf(const char * fmt, ...)

Function

The USART_printf function works like a standard printf function. The first argument should be a string, with format tags inserted as desired. There should be as many arguments following the first argument as there are format tags.

Prerequisites

- USART_init() and USART_tx_enable() must be called beforehand (only once)

Notes

- Certain special characters (of the \character variety) may not be displayed properly
- By default, the usb_printf function cannot format floating points. In order to enable the full version (or the lighter version) of usb_printf, see *Section 3.2 Linker Options: Setting up your project to use usb_printf() and usb_scanf() and the standard C math library on Page 7.*
- See available formats here: http://www.cplusplus.com/reference/clibrary/cstdio/printf/
- Remember that with the LCD display, you must explicitly control the cursor position with special control character sequences that are unique for each model of LCD. Read the LCD manual!

Tips, Tricks, and Common Errors

- Students often mistakenly use the function printf, as opposed to USART_printf. If nothing is displaying on the terminal, then this may be the reason.

Sample

```
USART_init(9600,USART_ASYNC); //Set baut rate to 9600
USART_tx_enable();          //enable transmission

USART _printf("decimal: %d\n",77);          //formatting using %d
USART _printf("4-digit hex: %04X\n", 77);  //formatting and padding using %04X
```

Result

```
decimal: 77
4-digit hex: 004D
```

See Also

- USART_init()
- USART_tx_enable()